PRELIMINARY ANALYSIS OF THE ECOLOGICAL INFLUENCE OF RURAL TO URBAN MIGRATION USING STATISTICAL INFORMATION DERIVED FROM STIRPAT MODEL

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Abstract. Using statistical information, this paper examines the influences of migration on China's urban environment, from atmospheric to geographical considerations, taking full account on the adverse and beneficial effects of destination (urban) and origin (rural). Migration accompanies industrialization and urbanization as one of the most important determinants of social development. Especially China, a rapidly urbanizing developing country has been recognized as one of the extreme examples for this. While migration has helped China's economy to reach a higher level than predicted, the urban environment has been overwhelmed by the sudden increase in population, reducing it carrying capacity. This study incorporates the evidence of previous studies to provide a kernel of scientific findings and statistical evidences that support theoretical works.
Keywords: *environmental protection, rural-urban migration, ecosystem, statistics, urbanization*

Introduction

Since primitive societies, "survive and thrive" have been the preeminent goals of human activities. However, contemporary pursuits for rapid economic and industrial advancements generally neglect the carrying capacity of urban settlements. Industrialization and urbanization on a global scale have stimulated a rapidly growing overheated economy with increasing demands. This urges frequent interregional migrations of the population from rural areas toward cities, where immigrants serve as cheap laborers. While the large numbers of migrant populations congregating in cities have contributed to economic growth, the intensification of human activity has caused irreversible disturbance and damage to urban ecosystems.

Currently, the phenomenon of frequent population migration has become a prevailing incident. According to the UN Population Division, in 2020, the total count of global immigrants will be 280.6 million (3.6 percent of the world's total population); in 2050, would be 5.2 percent of the world's total population as this number is anticipated to reach 470 million. As shown in *Figure 1,* international immigrants gather in More Economic Developed Countries (MEDCs), comprising over 20 percent of the total populations in Saudi Arabia and Australia and over ten percent in the USA and the majority of EU nations. Nevertheless, the instability of the population, altering age structure, and uneven spatial distribution of urban

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settlements brought about by constant migration inevitably tilt the area's ecological balance.

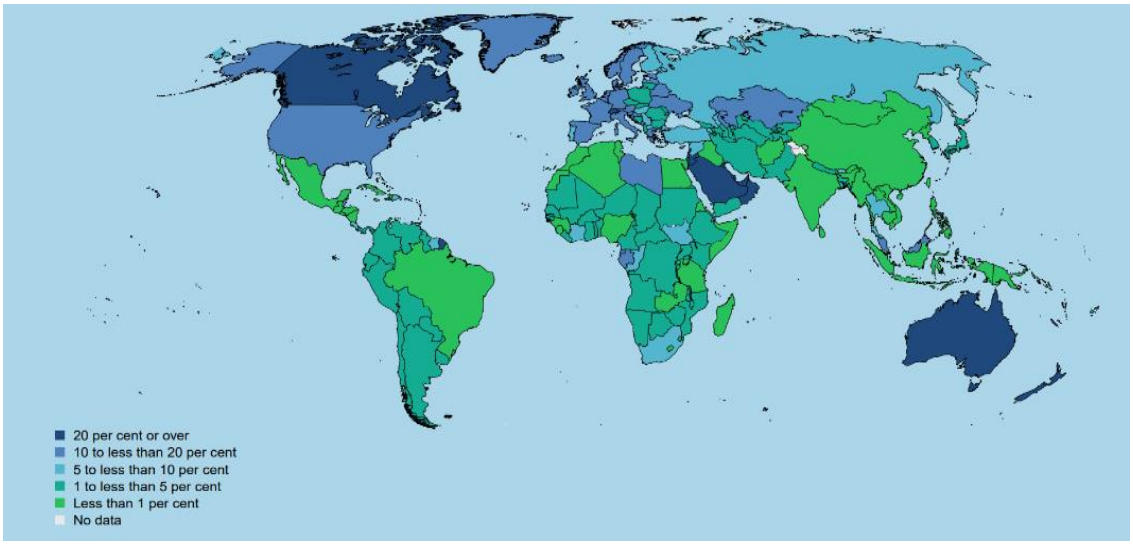

Figure 1. *Percentage of migrants as part of the total population (from the UN population division)*

Urbanization and migration in China

According to China: Promoting Efficient, Inclusive, and Sustainable Urbanization, over the last 35 years, urbanization has proliferated, with the urban population in the total population rising from less than 20% in 1978 to 52.6% in 2012, and the urban population increasing by more than 500 million. The majority of the growing urban population was influenced by China's massive urban-rural migration, from rural to urban areas, and from agricultural to industrial manufacturing, contributing to steady GDP growth of 10%. As shown in *Figure 2*, China experienced a downfall in annual urbanization from around 5% to 2%, whereas the world, low/middle/high-income countries all suggest a mild-mannered trend with merely any fluctuations. Therefore, several statistical measures in this study are taken from earlier stages with a more rapid urbanization level.

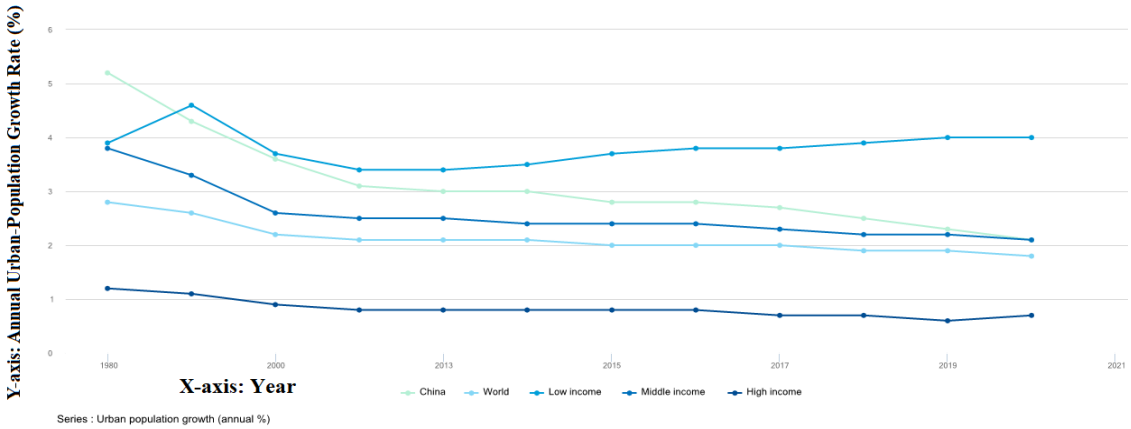

Figure 2. *World Bank Data of urban population growth (1980-2020); x-axis: year, y-axis: annual urban-population growth rate (%). (Graph was adopted from World Bank database)*

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Concept and terminology narrative

The term "migration" in this article refers to the statistical quality of the migrating population; in other words, the flow of persons who have moved their domicile. The population inflow and outflow rates might be calculated using *Equations 1* and *2*, reflecting the population influx and outflow situation, respectively. *Equation 3* takes into account the computation of a region's population net flow rate, which is the region's overall capacity to attract and retain floating people.

$$\text{Registered population} + \text{inflow population} - \text{outflow population} = \text{permanent residents} \quad \text{(Eq.1)}$$

$$\text{Population inflow (outflow) rate} = (\text{inflow population (outflow population)}) / (\text{Registered population}) \quad \text{(Eq.2)}$$

$$\text{Net flow rate} = (\text{inflow population minus outflow population}) / (\text{registered population}) = \text{inflow rate minus outflow rate} \quad \text{(Eq.3)}$$

The urbanization rate in China is calculated using data from the inhabitants' unique registration system (hukou). A city's population may be divided into three types:

1. OUs, old urban inhabitants who registered with the urban hukou before 1980.
2. NUs, after 1980, new residents who are rural-urban migrants acquire an urban hukou.
3. MUs, unregistered rural-urban migrants who live in a city but do not have an urban hukou.
4. RRs, or rural residents who live in rural regions, relocate to cities and, depending on their hukou, become NUs or MUs.

The urbanization rate could be displayed through the following formula: Urbanization rate = (OU + NU + MU) / (OU + NU + MU + RR) (Shen et al., 2017).

Methodology

(1) Statistical Model: This study presents a comprehensive analysis of urban environmental degradation caused by mass migration using the STIRPAT model, the Stochastic Effects of Regression on Population, Affluence and Technology (STIRPAT), derived from previous research and data collected from the Chinese Census and migration statistics from the World Bank and the United Nations, balancing theoretical work and applied science.

(2) Literature Review: Comparing and contrasting mainstream literatures suggest an overall trend on the topic, however, indicates insufficiency and thus this study incorporates the converging points and derive alternatives rather than an absolute conclusion.

(3) Empirical analysis: In terms of research approach, most Chinese researchers examine the influence of population movement on the ecological environment qualitatively, but this work investigates the impact of population migration on the urban ecological environment statistically by expanding the STIRPAT model. Two primary models are established to assess the impacts of migration on the urban ecological environment and to evaluate the effects of migration and the local population. The environmental effects of migration are then measured by incorporating all of the city attributes into the model in a hierarchical regression, determining whether different city

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attributes affect the environmental effects of migration while distinguishing between the migrant and local populations.

An overview of rural-urban migration in China

The migrant throng's mobile movement, chiefly from rural to urban, progressively reaches a bigger size and has become a significant transformation in China's social advancement. According to the China Mobile Population Development Report 2021, the 244 million migrant population contributes 20% of the yearly GDP, highlighting the mobile population's strategic importance in performing its economic role. This principally fell upon the hukou system implemented in the late 1950s, which renovated and regulated rural labor migration to urbanized areas by establishing identification procedures that integrate with work distribution, education, and social welfare. The hukou system has helped visualize urban migration statistics over the past thirty years. Overall, from 1985-2015, more than 40% of total migrations were work-based and contributed 18.7% of GDP per capita growth between 1980 and 2010 (Ma and Chen, 2012). Further, China achieved the 100 million urban hukou conversion target by 2020 (Chan, 2021).

The net movement of Rural-Urban migration redistributes the population from rural areas to urban cities. *Figure 3* depicts a rising percentage of urban residents from 12% to a projected 80%, while the rural population decreases from 90% to an estimated 20%, exhibiting a negative correlation between the two statistics.

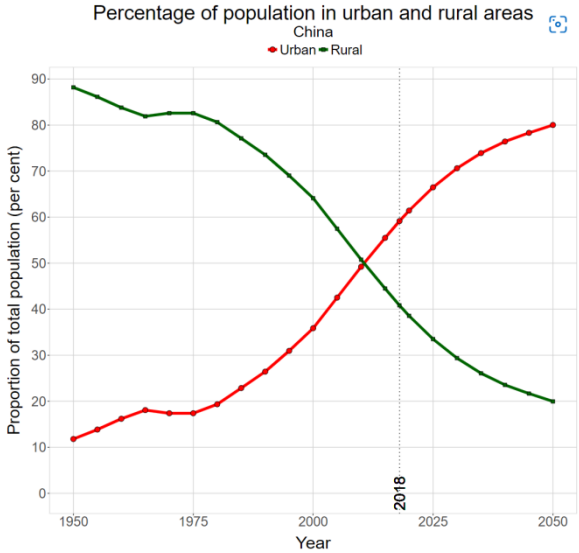

Figure 3. *The proportion of population in urban and rural areas in China (UN, 2018)*

This pattern is most obvious in the Pearl River Delta (PRD) region of southern China, as shown in *Figure 4*, which is reflected in the darker areas with higher net migration rates. The PRD is comprised of central manufacturing quarters, Foshan and Dongguan, enterprise clusters, Shenzhen, and Guangzhou, and more specialized districts providing financial, recreational, and administrational services. As early as 2003, migrant workers already accounted for about 45% of the total population of the PRD. In 2005, the PRD urbanization level reached about 60% based on the hukou

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registration system. If the caliber of the actual population living in the towns is taken into account, the level of urbanization reaches about 80%. By the end of 2005, Hong Kong business people had set up more than 80,000 enterprises in Guangdong, employing over 10 million people. Driven by the export-oriented economy, urbanization rose from 19.8% in 1982 to 60% in 2018 (Liao and Yip, 2018). It is not only the Pearl River Delta region that is booming, but it can be seen that the general trend has covered the entire southern region of China from 2005 to the present.

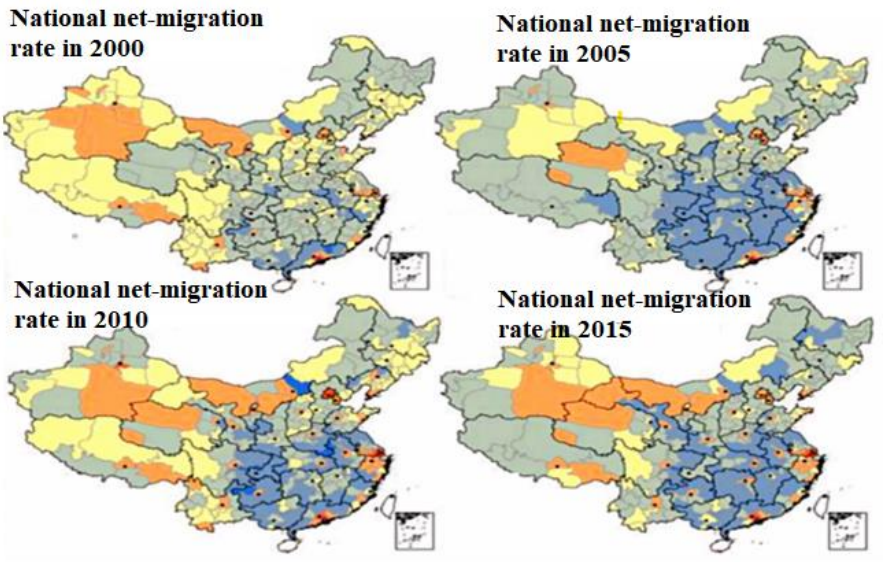

Figure 4. *China's county-level net migration rate variations (Liu and Liu, 2021)*

Accompanying a boost in urbanization and economic progressions, China's urban environmental problems have also come to the fore, with most cities facing excessive ambient air quality, shortages and severe pollution of water resources, drastic increases in waste generation, and irrational and inefficient land use structures (Chen and Zen, 2008). Thus, our research reveals that the overall migrant population and population density have an impact on the urban ecological environment. Furthermore, this research aims to give theoretical support for studying the influence of population movement on China's urban environment.

Advances in the theory and methodology of the ecological influences of migration and population growth

Scholars' understanding of the merely one-sided environmental influences of migration has gradually shifted from the initial consideration of the relationship between the two to a more rational and objective appraisal, which concerns the entire civic ecosystem. Therefore, this study epitomizes the dilemma based on a summary of existing research results, including three doctrines: Malthusianism, Classic Economics, and the theory of Sustainable development as well as a framework defined by New-Type Urbanization and Kuznets Curve.

(1) The pessimist school of thought based on Malthusianism warned that while the population grows geometrically, food resources grow only in arithmetic proportions, thus setting the stage for a chronic shortage that would require an adjustment of the

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birth rate. It sees uncontrolled population growth as inevitably leading to the depletion of resources in terms of exponential population and geometrical growth of living resources (Malthusian Theory of Population | Thomas Malthus in ECONOMICS).

(2) The classical school of economics led by Adam Smith and Karl Marx believed that technological advances could cope with population growth and that urban settlements would therefore remain in optimum condition.

(3) The theory of sustainable development. The United Nations Sustainable Growth literature arose primarily in response to a rising interest in understanding the linkages and possible conflicts between economic progressions and the environment (IPCC). This theory makes extensive use of multivariate analysis to argue that social elements such as population, economics, and environment are always changing. Traditional ideas have steadily fallen out of step with reality, and subjective, linear correlations are no longer a reliable indicator of the link between population and environmental damage.

(4) New-Type Urbanization. In China, new-type urbanization has been defined as a transitional version of conventional urbanization that decreases pollutant emissions while increasing energy efficiency. Both strict government limitations on pollution emissions and active foreign investment are important measures that fundamentally contribute to pollution reduction and efficiency in this new type of urbanization (Yu, 2020).

(5) Based on the notion of the Environmental Kuznets Curve (EKC). According to the Urbanization-EKC (UEKC) theory, during the urbanization process, the quality of the ecological environment degrades and then improves in a 'U' shape. The coupling curve between urbanization and the Ecological Quality Index (EQI) is determined to be a composite function with logarithmic and quadratic components, with a 'U' curve form of rapid drop and sluggish ascent (Fang et al., 2021).

The population directly affects the quality of the environment through production and consumption activities and indirectly through its socio-economic activities. Researchers believe that the relationship between the two is best grasped when the full range of demographic, resource, environmental, economic, social, and technological considerations are considered.

Ecological effect of rural-urban migration on source environment

This study focuses on the impact of population dynamics on ecological balance, which the scholars argue plays a significant role as migration flows reallocate and ravage inadequate resources. Thus, theological advancements regarding various aspects of migration are summarized in this study to apprehend results both favorable and unfavorable for sources and destinations.

Positive ecological effects on source environment

The soothing effect of population movement on the source environment. From the outlook of sustainable development, the positive effect of labor migration on the development of the ecological environment in the source is affirmed, especially in rural areas with predominantly mountainous terrain and areas with a more fragile ecological environment.

The migration of people vacating these ecologically feeble regions has avoided deforestation, steep slope clearing, reduced desertification, and soil erosion. Thus, the mobility of the population considerably eased the pressure on the ecological

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environment. Remittance migration has also resulted in a change from non-agricultural occupations of the majority of rural populations, which has reduced the exploitation of natural resources and the environment (Li et al., 2015).

Negative ecological effect on source environment

The negative impact of population migration on the place of departure. The main impact is on the use of land resources.

(1) The labor force reduction causes idle and wasteful resources. Most of the population migration is from economically backward rural areas to urban areas, and the loss of productive labor increases the environmental pressure in areas with a low population-to-land use ratio. Qin (2009) found that most of those who moved out were male adults, while most of those left behind were elderly and children. The scarcity of arable land for a population with limited labor capacity would increase the rate of land abandonment and fallow period, as well as desertification of arable land and conversion of agricultural ownership to industrial or business property, resulting in environmental contamination in enterprises.

(2) Irrational land resource use. Many also argue that income and migration remittances may also negatively affect the environment by increasing investments in environmentally destructive livelihood activities or by deteriorating the knowledge systems that have traditionally guided natural resource management (Dietz and Rosa, 1994).

Ecological effect of rural-urban migration

Positive ecological effects on urban environments

The favorable impact of population movements on the environment of the destination. This impact is consistent with neoclassical economics, accentuating the role of population agglomeration effects and technological progress. The main influences include:

A beneficial reduction in the concentration of some significant pollutants in the atmosphere. Shen et al. (2017) assessed the impact on pollutant emissions and health associated with the RTC in China from 1980 to 2030 with an approach of studying $PM_{2.5}$ (Atmospheric particulate matter (PM) less than 2.5 microns in diameter) emissions and concentration. *Figure 5A* shows the general trend of decreasing urban $PM_{2.5}$ emission density of 0.1 G/Km^2, mainly in the Zhejiang and Jiangsu regions. In comparison, rural $PM_{2.5}$ emission density of 0.2 G/Km^2 is evenly distributed in East China. Similarly, *Figure 5B* depicts a net decrease of 15 μg/m^3 in $PM_{2.5}$ concentrations across the country. Overall, compared to 2005, China has reduced its carbon intensity by about 48.1% (Ma et al., 2022).

From *Figure 6*, the study concluded that the shift in energy consumption by the migrating population from the original predominantly biomass-based energy consumption to cleaner energy consumption optimizes the energy consumption structure in the destination, reducing the overall $PM_{2.5}$ concentration and has a favorable impact on the atmospheric environment. The national-wide mean exposure concentration of 58.6 mg/cubic meter is lower than the 62.5 mg/cubic meter estimated on the basis of zero net migration. More direct evidence of this is the reduction of 450,000 premature deaths in the 30 years from 1980-2010 (Shen et al., 2017).

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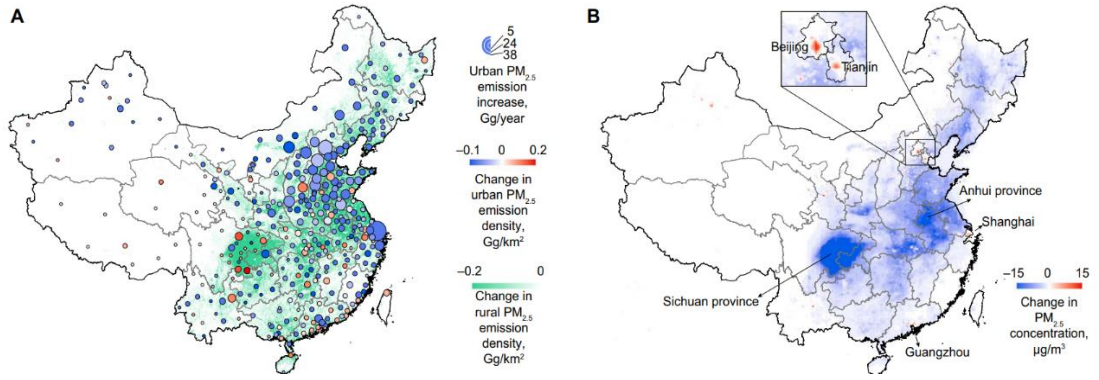

Figure 5. *Migration-induced spatial variation in $PM_{2.5}$ emissions and concentrations in China: (A) displays the density of primary $PM_{2.5}$ (fine particles) emissions in China during the last 30 years in relation to the size of the bubble. (B) displays primary and secondary modifications ($PM_{2.5}$ particles transformed after photochemical reactions in the atmosphere.) $PM_{2.5}$ concentrations (Shen et al., 2017)*

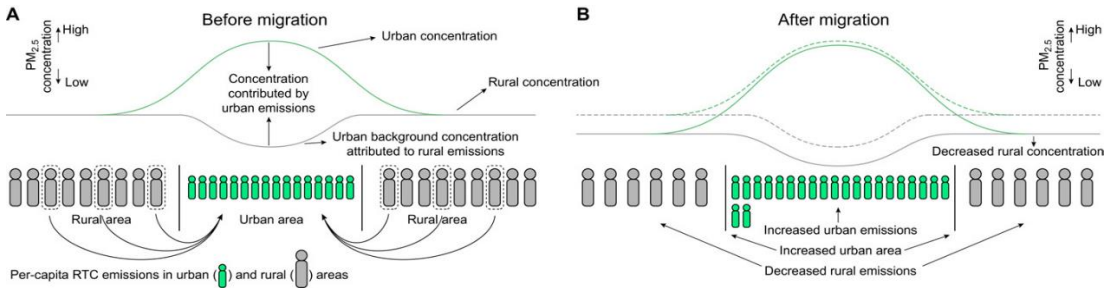

Figure 6. *Changes in urban and rural emissions and $PM_{2.5}$ concentrations as a result of population movements illustration (Shen et al., 2017)*

Negative ecological effect on urban environment

Adverse effects of population movements on the environment at destination. The results are consistent with the traditional Malthusian view that emphasizes the finite nature of resources and environmental growth, thus suggesting that a significant increase in the total population will lead to resource shortages and environmental degradation in redistributed areas. The significant repercussions include depraved atmospheric conditions, irrational land use, and idled water sources.

(1) Deplorable state of the air environment's quality. Few empirical research has analyzed migration's influence on the urban atmospheric environment and found a considerable negative association between migration and metropolitan air quality after adjusting for other demographic, affluent, and technical characteristics. In particular, Lu (2020) revealed the deteriorating air quality in China. Secondary $PM_{2.5}$ emissions, such as NO_x and SO_2, are substantially greater in urban regions than in rural areas due to higher total consumption and investment levels of urban inhabitants. Population movement increased yearly NO_x, SO_2, and $PM_{2.5}$ emissions from primary sources by 1.42 million tons, 1.3 million tons, and 50,000 tons, accounting for 5.4%, 4.8%, and 0.4% of total national emissions, respectively, in 2012.

(2) Lead to irrational land use, reduced land-use efficiency, vegetation cover, etc. Large-scale rural-urban migration has boosted urban population and density. This

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induced continuous expansion of urban land use and increased the building land area by crowding out arable and ecological greenfield sites in the suburbs. Perz (2003) implies that agricultural production and additional residential area are attained through the removal of woods and extensive deforestation in rural fringe areas. Therefore, the intensity of land use has increased, the efficiency of land use has decreased, and hence the relationship between people and land has agitated. This is illustrated by the fact that expropriation of rural property fulfills about 90% of the demand for urban development land. Hardly 10% is supplied by the current supply of undeveloped urban building land and brownfield sites. Following this trend, the total area of urban building land reached 41,805 km^2, an increase of 58% in the last decade.

(3) Coercing water supply. Intensified urbanization would increase sewage discharge, exploit groundwater, and cause water supply idleness. The annual imbalance between urban water demand and supply in China is 6 billion cubic meters. Water is in low supply in 420 cities, with 110 of them having severe water resource limitations. The increase in the mobile population will compulsively change the proportion of water used by the local population in urban areas, affecting the overall water use efficiency and creating a degree of duress on water resources.

Conclusion and future outlooks

Overall, aspects discussed in this article are summarized in three points, based on pre-established theories and cross considerations from various perspectives. These effects are attributed to migration variables, primarily rural to urban. In future studies, a focus on the external causes of migration could be considered to elaborate on contemporary research fully. In summary, three aspects regarding the atmospheric and land environment and water resources are listed below.

The impact of migration on the state of the urban atmosphere. The population of urban areas has a significant impact on the overall atmospheric environment; the relationship is inversely proportional; in other words, more urban people result in lower air quality. When the economy is still emerging, the influence of migration on atmospheric conditions is generally more evident. As migrants make up a higher part of the urban population, the situation worsens. However, if the economy expands and cleaner and more efficient energy sources, such as nuclear and hydro energy, are created in cities, the atmosphere will deteriorate less as more rural residents relocate to cities. As a result, we may infer that atmospheric consequences are often severe in the short term, but eventually diminish and return to normal levels.

The impact of migration on urban water resources. The rises in the urban population would increase the amount of wastewater and domestic water, and the trend will amplify consistently, especially in the amount of wastewater. Through the city's advancement, residents possess a more significant effect on the increase of water usage than the newly arrived residents. This is because of the difference between their water-consuming customs, as the locals consume more water over other aspects aside from primary water usage. In contrast, the migrants still consume water to satisfy their basic needs.

Migration's influence on the urban land environment. Overall, the increased urban population will significantly increase the volume of home garbage and contract area. However, their desire for land utilization varies to some extent. As the migratory population grows, the demand for residential space grows substantially, and the

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influence of migrants on the area utilized for housing purposes grows from negligible to significant. Although the expanding migrant population has increased demand for land, the overall impact is still minor in comparison to the influence generated by natives. Because the locals often got a greater consuming capability, which would increase the rate of trash discharge and resource occupation.

The study suggests that the integration of the STRIPAT model provides empirical analysis and suggests the integration of theoretical work from the literature review. In general, demographic change in urban settings exhibits a variety of outcomes under the influence of technology and social change in particular cities. More detailed research should focus on the dynamic aspects of population, taking into account social issues.

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